

CLEAN SPECIFICATION PARAGRAPHS

A technique for fabricating a three-dimensional periodic structure having a period of about $1\text{ }\mu\text{m}$ or less in a material has a broad range of possible application in the fields of optical technologies and electronic technologies. However, its fabrication method is not developed yet, and a three-dimensional periodic structure with a period of about $1\text{ }\mu\text{m}$ or less has not been realized up to now. Among techniques which have been examined, the following two are main ones: (1) a method in which holes are formed in three directions by dry etching, as shown in Fig. 54, (E. Yablonovitch, "Photonic band-gap structures", J. Opt. Soc. Am. B, vol. 10, no.2, pp. 283-295, 1993); and (2) a method in which substrates with parallel square rods on them are opposed and bonded to each other, one of the substrates is removed by selective etching, and another substrate is opposed and bonded again to repeat the operation, as shown in Fig. 55, (S. Noda, N. Yamamoto, and A. Sasaki, "New realization method for three-dimensional photonic crystal in optical wavelength region", Jpn. J. Appl. Phys., vol. 35, pp. L909-L912, 1996). Up to now, these two ideas are not realized in the case that the period is about $1\text{ }\mu\text{m}$ or less and the number of periods is five or more.

To attain the above-described object, it is necessary to realize a three-dimensionally-periodic structure by a method

superior in reliability and reproducibility. For that purpose, to effect such a method, at least two kinds of materials are laminated sequentially and periodically, and sputter etching is carried out separately from or simultaneously with film formation with regard to at least a part of the laminated layers. This method can fabricate a three-dimensional periodic structure having a period of about 1 μm or less.

The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention will be better understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 37 is an explanatory view showing selective lamination used in one embodiment of the invention;

Fig. 48 is an explanatory view showing one embodiment of the invention;

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplification set out herein illustrates one preferred embodiment of the invention, in

one form, and such exemplification is not to be construed as limiting the scope of the invention in any manner.

Conventionally, the bias sputtering method has been utilized as a thin film formation process (metallization) for forming electrodes and wiring in LSI. For example, as shown in Fig. 5, it is utilized for embedding metal film wiring 10 in a dielectric 9 to flatten an upper surface, or, as shown in Fig. 4, for filling up a space between two wires 10 not to produce a hollow portion. On the other hand, it is entirely novel technique to employ bias sputtering or sputter etching for shaping the film described below.

According to the above, by developing the above-mentioned technique furthermore, it is possible to periodically provide material with nonlinear optical susceptibility, electrooptic material, transparent material, conductive material, or the like, inside the three-dimensional periodic structure. Thus, a great variety of electronic functions and optical functions can be realized.

According to the above, it is possible to periodically provide light emitting or light amplifying material inside a three-dimensional periodic structure, and a high efficient optical active element can be realized.

According to the above, it is possible to integrate functional parts such as a waveguide, resonator, branch, coupler, reflector, optical detector, or the like, inside a three-dimensional periodic structure in which at least two kinds of film transparent material having periodic recessed and projecting pattern is nearly periodically laminated sequentially, i.e., inside an artificial medium having cutoff characteristic for a certain light wavelength region. Thus, it is possible to effectively utilize the advantage of the non-radiative characteristic. It is possible to provide a semiconductor laser inside a three-dimensional periodic structure, and thus high efficient laser action without loss of spontaneously emitted light can be realized.

It is possible to realize a structure in which, on a substrate having two-dimensionally periodic recessed and projecting patterns with the axes of symmetry of orthogonal x- and y-axes on the substrate, at least two kinds of film transparent materials having common periodic recessed and projecting patterns are laminated sequentially and periodically. Accordingly, it is possible to realize optical biaxial anisotropy expressed by a diagonal dielectric tensor of any values.

While this invention has been described as having a preferred design, the present invention can be further modified

within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.